

OCD WORK UNIT NO. 3118A
USNRDL-TR-953
11 August 1985

**DISTRIBUTION OF VOLCANIC FALLOUT IN AND ABOUT
A ONE-STORY RESIDENCE**

by

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The work reported was part of a project sponsored by the Office of Civil Defense, under Subtask 3118A.

ACKNOWLEDGMENT

The authors wish to express their sincere thanks to Col. L. F. Springer and Lt. Col. V. N. Cordero, of the U. S. Army Mission in Costa Rica, for their generous assistance in overcoming many of the obstacles usually inherent in operations in a foreign country. The authors also would like to express their appreciation to Mr. R. W. Voss and Mr. R. A. Nelson, both of this Laboratory, for their assistance in the field phase of the experiment.

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SUMMARY OF RESEARCH REPORT

**DISTRIBUTION OF VOLCANIC FALLOUT IN AND ABOUT A ONE-STORY
BUILDING**

USNRDL-TR-953 , dated 11 August 1965

by F. K. Kawahara, R. J. Crew

PURPOSE AND OBJECTIVES

The purpose of these tests was to study the behavior of fallout in the environment of a one-story residence, using as a fallout simulant naturally deposited volcanic fallout, produced by Volcano Irazu, Costa Rica.

The experimental objectives were to determine: (1) The ingress of the particulate matter from flow through an entry window and an exit window under three entry conditions; (a) natural ventilation, (b) forced ventilation, and (c) forced ventilation with filtered intake air, and (2) the rate of deposition, size and mass distribution of particles on exterior concrete surfaces, galvanized sloped roofs, and a patio which represented any partially enclosed area.

SCOPE

The experimental site was a one-story residence surrounded by concrete walks and situated within the area which was covered with volcanic ash fallout. The effects of deposition rate and rain (both during and after fallout deposition) on the ingress, deposition, and redistribution were studied. Daily fallout collections were made, measured and observed to determine debris distributions in and about the residence.

SIGNIFICANT FINDINGS AND CONCLUSIONS

It was found that the particle size distribution of material collected inside the home was similar to that outside the home. The mass loadings inside were a factor of 50 less than those outside. It was concluded that, in the case of radioactive fallout, the ratio of outside dose to inside dose may be reduced significantly in the vicinity of the window through which air is moving.

For studies conducted outside and in the absence of any precipitation, the particle size distribution and mass deposited was uniform from one sample location to another. On this basis, it was concluded that reclamation tests using uniform distributed synthetic fallout are realistic even when the surface configurations are quite complex.

RECOMMENDATIONS

Any further eruptions by this volcano or any other volcano which creates sand-like fallout should be utilized for studies requiring large-scale simulation of fallout distribution.

ABSTRACT

The sand-like debris from Volcano Irazu in Costa Rica closely resembles the type of fallout produced by a near-surface or underground nuclear detonation. The activity of the volcano during April and May 1964 presented an opportunity to use this phenomenon in a field-scale study of some relationships between urban reclamation and nuclear fallout contamination. The eruptions of the volcano were frequent and the rates of arrival at the test site were dependent on wind direction and the severity of the eruptions.

The investigation was divided into two phases: (I) distribution of debris inside a one-story residence; and (II) distribution outside the residence. Phase I was concerned with the ingress of particles through open windows under conditions of: (a) natural ventilation, (b) forced ventilation, and (c) forced ventilation with minimal filtering. Phase II was concerned with the deposition and redistribution by wind, of particles on concrete walks, corrugated metal roofs, and partially exposed tile floors - each with and without rain.

In Phase I, it was observed that particle size distributions inside the house did not differ greatly from those deposited outside. Mass loadings inside were a factor of 50 less than those outside. It was concluded that, if this were a case of radioactive fallout, the ratio of outside dose to inside dose would be reduced significantly in the vicinity of the window through which air is moving.

In Phase II, it was observed that in the absence of rain, the particle size distribution and mass deposited was uniform from one sample location to another, only minor variations having been observed from day to day. On this basis, it was concluded that reclamation tests using uniformly distributed synthetic fallout are realistic even when the surface configurations are quite complex.

When rain accompanied the debris deposition, however, different results were observed. Particle size distributions and mass loadings

were a function of redistribution and varied with sample location. Deposits on roof surfaces will be significantly reduced but will accumulate in the gutters. In the case of radioactive fallout, a concentrated radiation source would result.

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INTRODUCTION

In the development of protective and reclamation procedures for use in reducing the effects of fallout from nuclear detonations, information on specific contamination situations is required to supplement the knowledge of gross weapon effects. Such information includes the deposition and distribution of nuclear debris in and about a residence. The production by a volcano of debris resembling fallout provided large-scale simulated fallout conditions for obtaining such information. A study was made of the distribution of the debris particles inside and outside a typical residence during April and May 1964. The information obtained can provide an essential link between theoretical studies of fallout and the actual nuclear situation.

BACKGROUND

Limited study, in reclamation experiments, has been made of the deposition and distribution of synthetic fallout on surfaces about buildings.¹⁻⁴ The buildings were Army barracks, and synthetic fallout was uniformly dispersed on horizontal surfaces around them and on their roofs. One investigation,¹ with the primary interest of determining the overall cost and effectiveness of recovery operations, provided the only data on the redistribution effects of wind and rain.

No tests were made of interior contamination of buildings during the aforementioned reclamation studies. However, some were made of fallout shelters. At Camp Parks, simulated fallout was allowed to enter the ventilation intake of an underground shelter.⁵ At Operation PLUMBBOB, during actual nuclear fallout, a shelter ventilation intake configuration was tested⁶ which was designed to eliminate the need for air filtration.

In the reclamation studies mentioned, synthetic fallout with a uniform particle size distribution was used. Uniformity of the mass level dispersed was emphasized but little study was made on the effects of wind and rain on the redistribution of the particles after they were initially deposited. Nor were wind and rain effects on particle size distribution studied, although it was known that the configuration of buildings, curbs, and other surroundings influenced the local surface winds, which in turn, influenced the particle deposition and redistribution.

The experiments utilizing synthetic fallout material have yielded conclusions which were extrapolated into radiological situations, through theoretical calculations based on a mathematical fallout model. An example of this has been the conversion of mass data into radiation readings by the use of mass-contour ratios.^{7,8} Conversely, a fallout model⁸ has been used to determine realistic fallout environments for reclamation experiments. The fallout model⁷ idealized some of the indeterminable variables to simplify the approach to the problem of determining particle size distributions and mass depositions resulting from nuclear detonations. For example, the mass distributions under these idealized conditions were assumed to be uniform and no consideration was given to redistribution by weather and its effect on particle redistribution. Data still remain to be determined which would allow the evaluation of non-idealized situations and their effects on particle distribution in and about a typical residential building, before and after redistribution by wind and rain.

Since 13 March 1963, Volcano Irazu in Costa Rica had been erupting almost continuously. The sand-like debris (called ceniza) from this volcano closely resembles the fallout that would be produced by near-surface or underground nuclear detonations.⁹ This resemblance and the falling out of the debris in populated areas afforded an opportunity to study the distribution of particulate matter in ventilated spaces and on exterior surfaces. Thus an experiment, using a residence with grounds, was undertaken to determine mass and particle size distribution of volcanic fallout, in interior spaces due to air flow, and on exterior surfaces. The distribution of particles on exterior surfaces was determined as a function of the different surfaces, and the interior particulate distribution due to air flow was compared with the exterior distributions.

OBJECTIVES

The specific objectives were to: (1) Study the ingress of particulate matter resulting from air flow through an entry window and an exit window under three ventilation conditions: (a) natural ventilation, (b) forced ventilation, and (c) forced ventilation with filtered intake air. (2) Study the rate of deposition, size and mass distributions of debris on exterior concrete surfaces, galvanized sloped roofs, and a patio representing partially enclosed areas. These depositions were studied on rainy days as well as rain-free days.

A secondary objective was to observe the current methods employed by the city of San Jose for mass removal of debris from buildings and streets in densely built-up areas.

EXPERIMENTAL PROCEDURES

TEST SITE SELECTION

The experiments had to be started as quickly as possible while the volcano eruptions continued. Also, most of the experiments had to be completed before the seasonal rains started. Detailed experimental planning had to await the selection of an adequate test area and the arrival of the test personnel.

The most suitable house obtainable was a one-story house (Fig. 1) outside the city where the sidewalks and paved roads were limited and foot traffic was practically non-existent. The house was within the fallout pattern, 10 miles downwind from the volcano (Fig. 2).

TEST EQUIPMENT

To determine the effect of surface winds on deposition or redeposition of particles on the exterior surfaces, wind speed and direction data were recorded continuously. Bendix-Friez Model 130 wind-measuring sets were used, which had wind direction-velocity transmitters and wind direction-velocity recorders.

Temperature and humidity were measured to determine what effect, if any, they might have on the mass and/or particle size distributions obtained. Records were obtained with a Brown Hygrothermograph Recorder, Model 612X21K1X84. The amount of precipitation in the tests on redistribution by rain was determined with standard 6-in. rain gauges.

The weights of samples collected were determined on a Mettler B-5 Balance or a Mettler K-7 Balance, depending on the size of the sample and the degree of accuracy desired.

NRDL 630-64



Fig. 1 Northeast View of House Used for Experimental Station

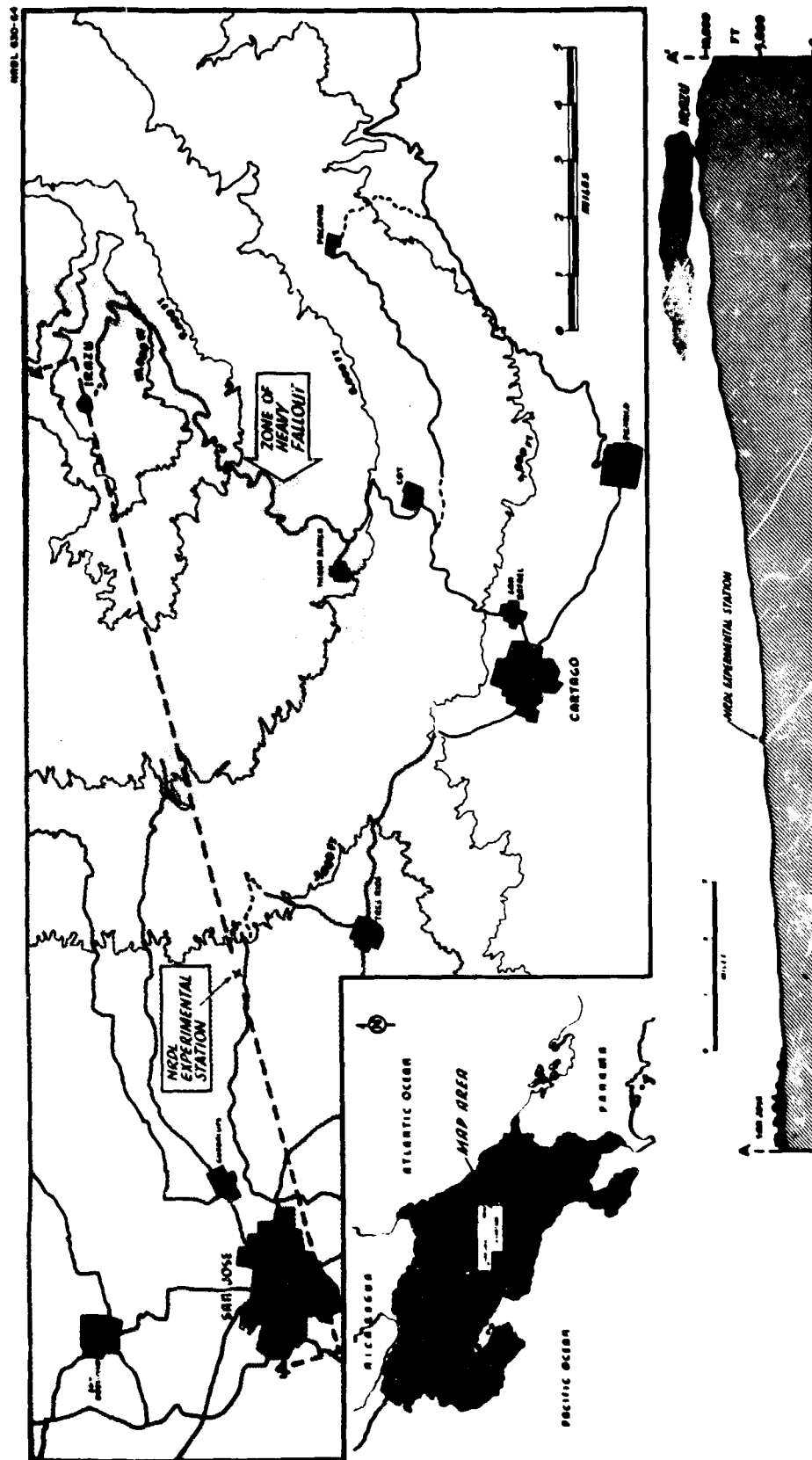


Fig. 2 Map of Fallout Area in Costa Rica

Cameras were used to document the experiments conducted at the house. Also obtained through photography were qualitative observations on the removal of debris from the streets of San Jose. A 16-mm movie camera (Cinema Beaulieu RC-16) and a 35-mm still camera (Besseler Topcon BT 300) were used.

SAMPLE COLLECTION

To obtain mass distribution data, an always-open collector (AOC) was used. This type of collector had been previously field tested and consisted of aluminum louvers placed at 45° inside a 2 x 2-ft, 2-in. deep aluminum tray. The AOCs were used in all tests, except one, with the louvers slanted northward, the direction of the prevailing winds. In the one exception, in which the objective was to determine whether direction of roof slope affected the mass distribution, the AOCs were placed with the louvers pointing up toward the roof ridge.

On the patio floor, vacuum cleaning was used to collect samples. This avoided alteration of the wind pattern at the surface of the floor, by trays on the floor. The vacuum cleaner used was a Filter Queen with a new, tared, debris-collector bag used for each test run.

To obtain data on the mass distribution on concrete and roof surfaces, the material deposited on a measured area was brushed into a tared container.

SAMPLE PROCESSING

To determine the gross weights of fallout collected in the AOCs, the debris collected was transferred into small aluminum weighing pans and weighed. To determine the amounts obtained by the brushing and vacuuming techniques, the amounts collected were placed in tared plastic bags and weighed. Mass per unit area was calculated by dividing the total mass collected by the total area swept or vacuumed.

Dry sieving, using standard sieves, was conducted in the field on samples to determine their particle size distribution. The sample was shaken in a Ro Tap Shaker for 10 minutes. The amounts retained on the

various sieves were carefully brushed into tared aluminum weighing dishes and weighed.

INGRESS TEST PROCEDURES

Three tests of debris ingress into the interior spaces were conducted (see Table 1 for details, Fig. 3 for sample locations). In Test Alpha, two windows on opposite walls of the house were left open for 19 hr, and the amount of fallout entering the space under conditions of natural ventilation was determined.

In Test Bravo, an exhaust fan was placed in one window and 3900 ft³ air/min (face velocity, 425 ft/min) was pulled through the other window. This experiment ran for 19 hr.

In Test Charley, the conditions were similar to those of Bravo, except that inexpensive furnace-type filters (Fram Aire Filters, 1-in. thick fiberglass) were put into the intake window. The filters lowered the intake air flow rate to 2800 cfm. The experiment ran for 25 hr.

EXTERIOR TEST PROCEDURES

The conditions for all exterior tests are listed in Table 1 (Fig. 4 shows plan view of sampler locations). Preliminary tests (Tests Delta and Echo) were conducted to develop procedures and techniques for the subsequent, main tests. In the latter each surface was examined with and without rain and with different mass loadings. One of the tests was run for the photographic documentation of the movement of the particles by rain.

As shown in Table 1, Tests Foxtrot, Hotel, and Juliet were conducted on the patio surfaces. One of the determinations from the preliminary tests (Delta) had indicated that placement of AOCs on the surface of the patio would alter the natural air flow pattern. Therefore during all tests conducted on the patio surface, fallout trays were located outside of the patio area, and vacuuming techniques were used to determine the mass loadings within it. Foxtrot was run to determine mass deposited and particle size distribution of fallout around the patio in the absence of rain. Juliet was a repeat of Foxtrot but with the

TABLE 1

Summary of Conditions and Equipment Used for Particle Distribution Tests

| Test | Date (1964) | Duration (hr) | Location | Condition | Equipment |
|-------------------------------------|----------------|------------------|----------------------------------|--|-------------------------------------|
| <u>Ingress</u> | | | | | |
| Alpha | 9 April | 19 | Interior | Natural ventilation | 19 AOCs,* & WVD sets** |
| Bravo | 10 April | 19 | Interior | Forced vent., 3900 cfm | 19 AOCs, & WVD sets |
| Charley | 14 April | 25 | Interior | Forced vent. with mini- mal filtering, 2800 cfm | 19 AOCs, & WVD sets |
| <u>Exterior</u> | | | | | |
| Delta | 19 April | 19 | Patio | No rain | AOCs, WVD sets |
| Echo | 19 April | 19 | Concrete walkway (sloped) | No rain | AOCs, WVD sets |
| Foxtrot | 22 April | 22-1/2 | Patio | No rain | 10 AOCs, & WVD sets |
| Golf | 22 April | 22-1/2 | Concrete walkway (sloped) | No rain | 9 AOCs |
| Hotel | 25 April | 44 | Patio | Rain | 10 AOCs, & WVD sets, rain gauges |
| India | 25 April | 44 | Concrete walkway (sloped) | Rain | 9 AOCs, rain gauges |
| Juliet | 28 April | 6 | Patio | No rain | 10 AOCs, & WVD sets |
| Kilo | 28 April | 6 | Concrete walkway (sloped) | No rain | 9 AOCs |
| Lima | 28 April | 6 | Roof | No rain | 4 AOCs |
| Mike | 30 April | 25-3/4 | Concrete walkway (horizontal) | Rain | 2 AOCs, rain gauges |
| November | 30 April | 25-1/2 | Roof | Rain | 5 AOCs, & WVD sets |
| Oscar | 30 April | 1-1/2 | Concrete walkway (sloped) | Rain | Rain gauges, cameras |
| Papa | 30 April | 8-1/2 | Concrete walkway (horizontal) | No rain | 3 AOCs |
| Quebec-1) Quebec-2) Quebec-3) | 2 May | 18 total | Roof | With and without rain | Brush collection |
| Romeo | 2 May | 4 | Concrete walkway (sloped) | No rain | 5 AOCs |

* Always Open Collector.

**Wind Velocity and Direction Transmitter and Recorder sets.



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debris falling at a different mass loading rate. Test Hotel was run with rain to see whether this altered the distribution of particles.

Tests Golf, India, Kilo, Oscar and Romeo were conducted on the sloped (8 %) concrete walkway. The purpose of the first three of these tests was to determine the mass deposited and the particle size distribution, Golf and Kilo being run without rain and India with rain.

The purpose of Test Oscar was to record on movie film the action of rain on particles. The amount of rainfall was documented with rain gauges. No experimental data on mass deposited was taken.

Test Romeo was run to determine deposition amounts as a function of distance from the house. Fallout trays were placed at known distances in a row from the house. If the prevailing wind remained constant for a specified period, the amount deposited was expected to be a function of distance from the house.¹⁰ The configuration of the house was expected to alter the mass distribution and the amount would vary with distance from the house.

Tests Mike and Papa were conducted on the horizontal concrete walkway located in front of the house, with and without rain, respectively. The mass deposited and the particle size distributions were determined.

Tests Lima, November, and Quebec-1, Quebec-2, and Quebec-3 were conducted on the roof. For Test Lima, one AOC was placed on each of four slopes facing north, east, south, and west respectively. The purpose of the test was to determine whether direction of slope introduced any difference in the amount collected. Test November was a repeat of Test Li. with rain. The three Quebec tests were conducted to determine the effect of rain on the particles already deposited on the slanted roof. The amount of debris deposited was determined by brushing and weighing material within an area of known dimensions. The amount of material collected or deposited before and after rain was weighed. No particle size analyses were made of Quebec samples. Visual estimates were also made on the amount of material removed from the roof and redeposited in the gutters.

RESULTS AND DISCUSSION

Particle size distributions (Appendix A) were obtained through sieve analysis of some samples at the test site. Sieve analysis data from interior and exterior stations, for several test runs, were plotted (Figs. 5-9) to determine the mass median particle sizes.

The mass per unit area determined for each sample is presented in Appendix B.

For ingress studies, the total amount of fallout entering the experimental space for each of the three tests was estimated by sketching contours (based on fallout collections and visual estimations) on a plan of the space, determining their areas, and multiplying by the mass per unit area values of the contours. Figure 3 includes, as an example, the contours estimated for Test Bravo.

Rain, temperature, and relative humidity data are presented in Appendix C. These data show only minor variations during the period of these tests, and no correlation with particle size distribution is apparent.

INGRESS STUDIES

The data in Table 2 and the interior data in Appendices A and B show that the amount of debris collected and the particle size distributions (Figs. 5-7) were fairly similar at the roof and exterior window stations for Tests Alpha and Bravo. However, for Test Charley the roof station collected only half as much debris as did the exterior window station. This was due to the low deposition rate during this test and to the collection at the yard stations of material blown down from the roof and from nearby trees by strong winds during part of the test. Although the exterior window station was relatively close to the intake window, it was far enough away so that under the conditions of Test Charley, its collection could not be relied upon to represent the debris

TABLE 2

Summary of Selected Field Data and Derived Data for Ingress Tests

| Station | Total Mass (g) | Mass Loading (g/ft ²) | Mass Med. Diam. (μ) |
|---------|-------------------|--------------------------------------|------------------------|
|---------|-------------------|--------------------------------------|------------------------|

Test Alpha

Wind: Light (< 3 knots) and variable.

Ventilation: Natural.

Total Debris Entering Test Space: 16 g

| | | | |
|--------|------|------|----|
| Roof | 42.9 | 10.7 | 82 |
| Window | 50.1 | 12.5 | 85 |
| 1 | 1.9 | 0.47 | 57 |
| 2 | 0.48 | 0.12 | 47 |
| 15 | 1.6 | 0.40 | 60 |

Test Bravo

Wind: Light (< 3 knots) and variable.

Ventilation: Forced, 3900 cfm.

Total Debris Entering Test Space: 21 g.

| | | | |
|--------|------|------|----|
| Roof | 21.5 | 5.4 | 56 |
| Window | 23.9 | 6.0 | 55 |
| 1 | 2.3 | 0.57 | 66 |
| 2 | 1.1 | 0.27 | 53 |

Test Charley

Wind: 6 to 12 knots - north to northeast during the day; light and variable at night.

Ventilation: Forced with filtered intake, 2800 cfm.

Total Debris Entering Test Space: 27 g.

| | | | |
|--------|------|------|-----|
| Roof | 14.9 | 3.7 | 94 |
| Window | 25.8 | 6.5 | 110 |
| 1 | 5.3 | 1.3 | 90 |
| 2 | 1.1 | 0.27 | 60 |
| 15 | 1.2 | 0.29 | 100 |

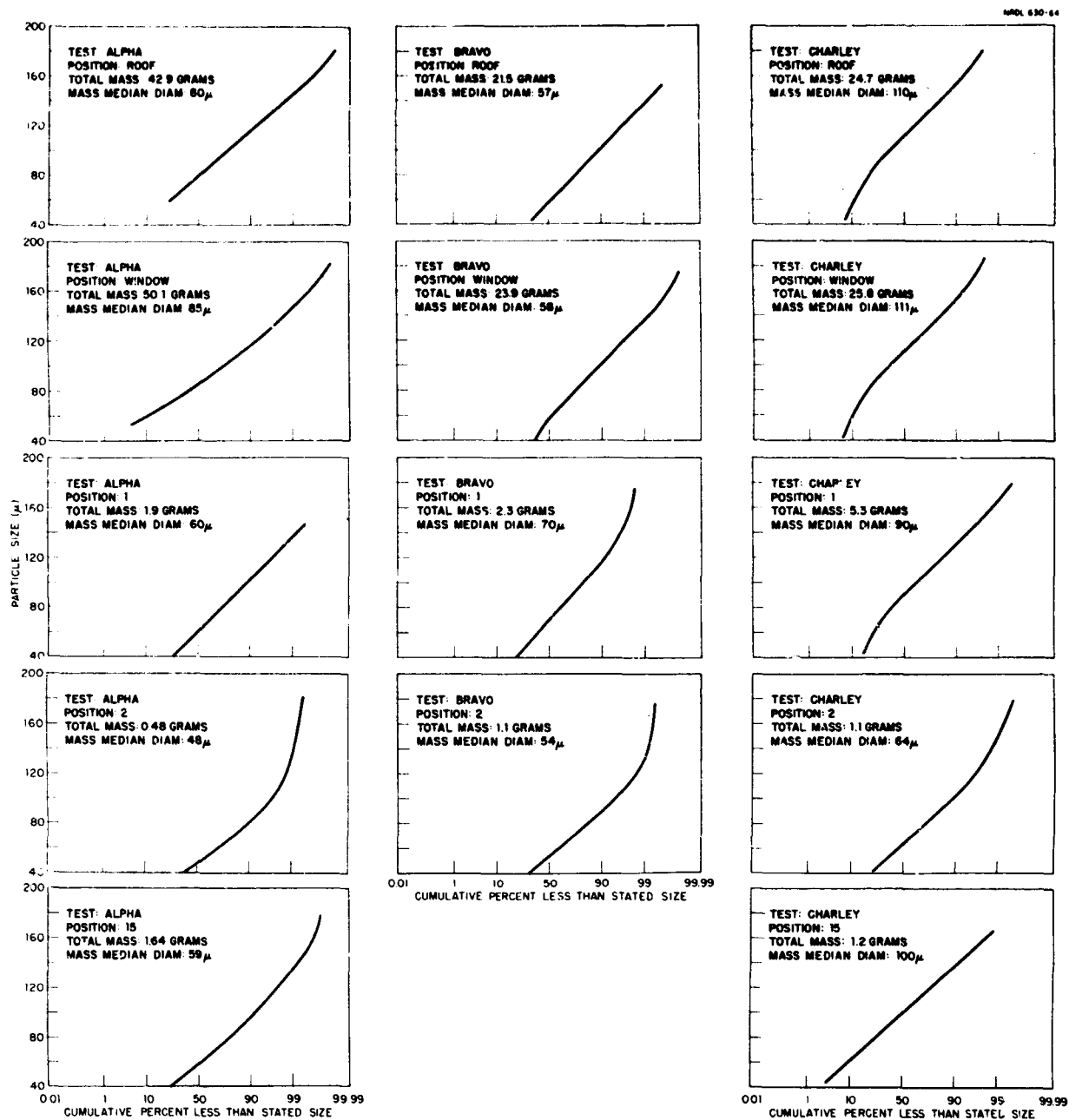


Fig. 5 Particle Size Distribution Test Alpha.

Fig. 6 Particle Size Distribution Test Bravo.

Fig. 7 Particle Size Distribution Test Charley.

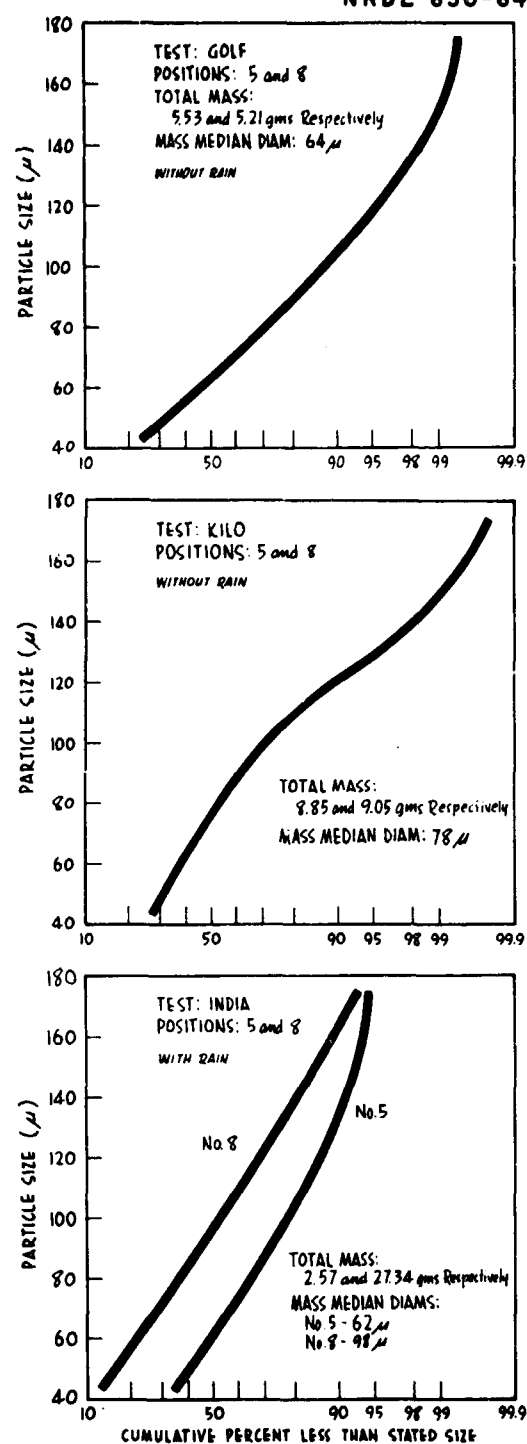
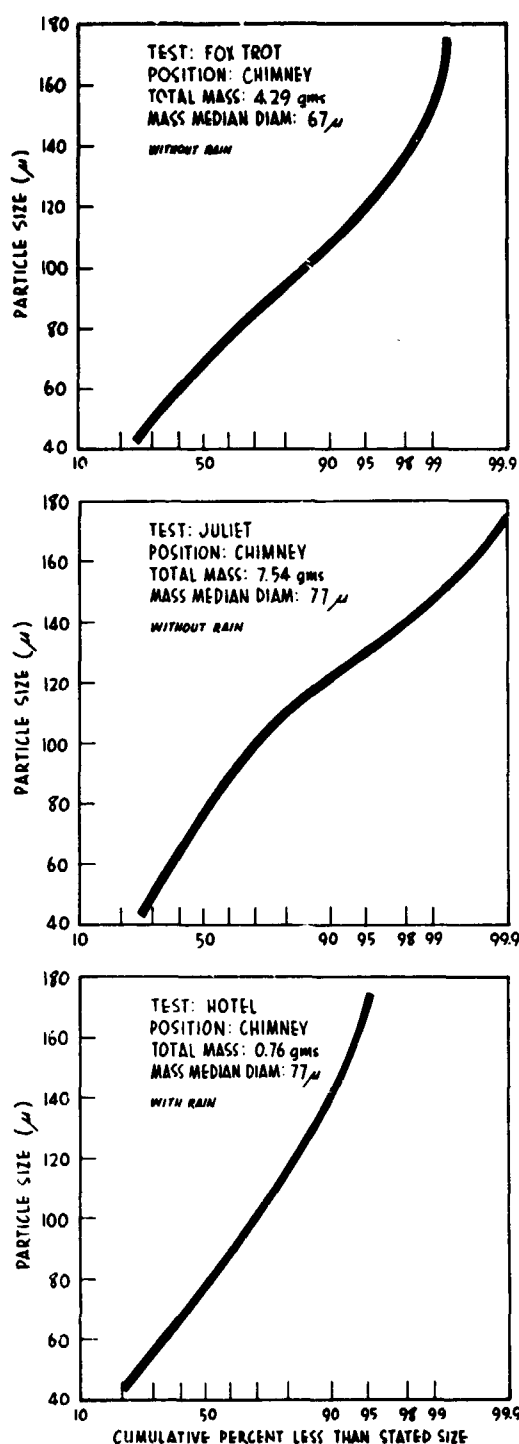


Fig. 8 Particle Size Distribution of Foxtrot, Juliet and Hotel.

Fig. 9 Particle Size Distribution of Golf, Kilo, and India.

close to the window. Thus, while the uniformity of deposition during Alpha and Bravo allows semi-quantitative evaluations to be made of their data, the variable deposition of Charley (along with uncertainties of flow rate caused by a component of the wind blowing into the intake window) allows only qualitative evaluations of the latter test. Table 2 shows that, as would be expected, considerably more total mass entered the house (in relation to that deposited outside) under the Bravo than under the Alpha conditions. Test Bravo, therefore, will be discussed below as being the "worst reasonable case."

Figure 6 shows that the particle size distributions within the house (those accounting for the majority of the mass) do not differ greatly from those outside. Therefore, if this debris were radioactive fallout, the specific activity (curies per gram) would be expected to be the same inside and outside the house. If all other sources are temporarily ignored, it is possible to estimate the radiation field due only to interior contamination in the vicinity of the window relative to an assumed uniform radiation field, I_0 , outside the building. Figure 3 indicates that most of the fallout in the house was confined to an area of about 200 ft². Dividing the total mass that entered the room by 200 shows the mass loading near the window to be about 0.1 g/ft², compared to the 5.5 g/ft² outside the window. Due to its finite extent of 200 ft², the radioactive field near the window in the room would be less by a factor of about 5 than that due to a field infinite in extent.⁵ With a mass loading in the house reduced by a factor of 55 (i.e., 5.5 g/ft² outside/0.1 g/ft² inside) and a reduction of 5 due to geometry, the field I_1 near the window (due to ingress of fallout) would be less than that outside by a factor of about 250.

Now, for the case of no fallout ingress, the radiation inside would be less than that outside, because of the shelter effectiveness inherent in most buildings. This protective effectiveness can be expressed by the ratio of the outside radiation field I_0 to the interior field I_2 contributed from outside, thus

$$I_0/I_2 = X$$

By neglecting small contributions from sky shine and other sources the total interior radiation field I_T is then represented by the sum of I_1 and I_2 , or

$$I_T = \frac{I_0}{250} + \frac{I_0}{X}$$

$$I_T = I_0 \left[\frac{1}{250} + \frac{1}{X} \right]$$

Therefore, the actual protective effectiveness

$$X_T = \frac{I_0}{I_T} = \frac{250 X}{250 + X}$$

From this expression it is apparent that the radiation protection originally provided in the region of the window is reduced when air is drawn into the room during a fallout event. The following table contains a solution of the above equation for a number of arbitrary X values. A comparison of X and X_T values clearly shows how serious interior contamination could become for the more highly protective structures. The ratio of X_T to X is also given in the table to further demonstrate this effect.

| X | X_T | X_T/X |
|------|-------|---------|
| 5 | 4.9 | .98 |
| 10 | 9.6 | .96 |
| 50 | 42 | .83 |
| 100 | 71 | .71 |
| 500 | 167 | .33 |
| 1000 | 200 | .20 |

However, due to the small area occupied by the majority of the fallout, it appears that it could be swept up easily and disposed of outside in a relatively short time (a few minutes). It may be that, because the inhabited space is located away from the open window, even this simple expedient is not required.

The amount of debris entering the room per square foot of window opening relative to the amount falling outside was 0.08 g/ft² per g/ft² for the natural ventilation condition of Test Alpha and 0.4 g/ft² per g/ft² for the 420 ft/min forced ventilation of Test Bravo. From Test Charley data, it appears that inexpensive furnace-type filters are ineffective in preventing ingress of fallout.

PARTIALLY ENCLOSED SPACE (PATIO)

For 19 hr during Tests Delta and Echo, the patio and the concrete walkway in front of the building collected 0.5 and 4.0 g/ft², respectively, or a ratio of mass deposited on a covered area to the mass deposited in an open area of 1:8.

During Test Foxtrot the average mass loading on the patio as determined by vacuuming was 0.2 g/ft². Pans placed on the perimeter collected from 0.7 to 1.2 g/ft². The pan closest to the front concrete walkway collected 1.0 g/ft², indicating a ratio of 1:5 between the patio and the front concrete walkway. Test Juliet gave 0.5 to 2.0 g/ft² around the perimeter, with the pan closest to the front concrete walkway giving 1.7 g/ft². Figure 8 shows the particle size distribution for samples taken during Tests Foxtrot and Juliet.

During the patio test with rain (Test Hotel), the collectors around the perimeter collected 0.8 to 10.6 g/ft². This wide variation of mass deposited was the result of run-off from the roof and splash-in from the ground surrounding the pans. Therefore, the results from pans close to the ground must be neglected. The more realistic results were obtained from the collectors located in the yard areas, on top of wooden boxes where collections of 0.2 to 0.8 g/ft² were observed. The particle size distributions of a sample from Test Hotel are shown in Fig. 8 for comparison with results from Tests Foxtrot and Juliet. Visual observations of tests on the patio indicated gradual buildup of windrows with time. These windrows were parallel to the direction of the wind and approximately 2-5 in. apart for winds of 5-10 knots. The amounts redeposited by the winds flowing through the open spaces of the patio were lower than those deposited in collectors located on the roof or in the yard area, but they were much greater than those which entered the interior test spaces. Thus, the protection offered by the partial cover of the patio might represent a "worst possible" interior case, in which all the windows are blown out.

OUTDOOR STUDIES

Grounds and Walks

Figure 9 shows the particle size distributions of typical samples from the back concrete walkway during Tests Golf, Kilo (without rain), and India (with rain). The masses deposited for Golf and Kilo were very uniform, 1.3 to 1.4 g/ft² and 1.7 to 2.4 g/ft², respectively. The mass deposited in Test India varied widely, 0.6 to 15.3 g/ft², and was a function of the lawn "density" - amount of grass versus amount of bare soil - near the fallout collector. Where the lawn "density" was greater, the collections were lighter.

In Test Romeo, which was intended to show variation of mass deposited as a function of distance from a building, the results were very inconclusive because of variable winds. All samples taken between 12 and 60 ft west of the house amounted to 0.5 to 0.6 g/ft².

Tests Mike and Papa on the front concrete walkway, with and without rain, respectively, essentially confirmed previous test results from Golf and India on the back walkway.

Roofs

For tests on the roof surfaces, it was found that deposition without rain (Test Lima) on the four different slopes of the roof was approximately the same. All collections ranged from 1.9 to 2.3 g/ft². Sample location did not appear to have any bearing on the mass deposited or the particle size distribution. However, when rain fell (Test November), the mass deposited varied with sampling location. The south slope collected approximately 1/2 the amount collected on each of the other three slopes, although the size distributions were approximately the same.

In Test Quebec-1, the north, east, and south slopes all indicated 2.3 to 2.6 g/ft² deposited. After approximately 24 hr the same (cleaned) areas gave 3.0 to 3.4 g/ft², while adjacent areas not previously sampled showed 4.3 to 6.3 g/ft². After a light rain (< 0.01 in.) these same (cleaned) areas gave 4.2 to 5.7 g/ft² and 5.2 to 6.8 g/ft², respectively, indicating not only that no redistribution occurred but that additional debris came down with the rain.

In Test Quebec-2, the roof deposit before rain showed 27 to 32 g/ft² as determined by brushing an area clean. After a heavy rain (0.15 in.) this same (cleaned) area showed 5.3 g/ft², while an adjacent unsampled area showed 5.7 g/ft². Quebec-3 was a continuation of Quebec-2.

After about 0.20 in. of rain, the residual on the roof was only 0.03 g/ft² on all areas sampled. Although the roof itself was cleaned by the rain, the majority of the debris became concentrated in the gutters, below the roof surfaces. The flowing rain water did not remove the debris from the gutters, and manual methods were employed to remove the debris after the rain.

WEATHERING EFFECTS

Examination of the wind speed and direction data indicated zero or very little winds during the night and variable wind speed and direction during the day. Small gusts of winds were detected during the day but these gusts were always below 10 knots.

The observations on the movement of debris particles by rain and wind were extrapolated to a radiological situation. Since the radioactivity is associated with the particles and removal of the particles means removal of the radioactivity, the removal of the fallout from the sloped galvanized roof to the roof gutters does not alleviate the radiation problem for a person living in this house. The material merely is more concentrated. The 0.15 in. of rain observed removed a very high percentage of particles from the roof but drained little from the gutters. A redesign of the gutter system to include some slope in the gutters is indicated to help remove much of the debris. The removal of the debris to a greater distance from the house also would have to be considered.

RADIOLOGICAL CONSIDERATIONS

Further extrapolation of the data obtained from these tests to a similar nuclear fallout situation was made using the information presented in Reference 8. It was assumed that the test station was located on the hot line of the fallout pattern from one detonation, 10 miles downwind from the point of detonation. Other input values (mass and particle size) determined from the concrete walkway tests (Tests Golf and Kilo) were specified. The input values used were as follows:

Mass deposited: 1.3-1.4 g/ft² (Test Golf)
1.7-2.4 g/ft² (Test Kilo)

Maximum particle size: Approximately 300 μ
Distance downwind: 10 miles

With the mass deposited determined from the tests assumed to be the deposited initial mass, the solution, for a weapon yield of 10 KT from Table C.2, Reference 8 is:

| Downwind Distance (ft) | Standard Intensity (r/hr) | Particle Diameter Range (μ) | | Deposited Initial Mass (mg/ft ²) | Mass Contour Ratio (mg/ft ² /r/hr at 1 hr) |
|------------------------------|---------------------------------|--------------------------------------|---------|---|---|
| | | Minimum | Maximum | | |
| 50017 | 206.53 | 238.6 | 351.0 | 1704.9 | 8.255 |
| 54093 | 190.72 | 222.5 | 320.4 | 1474.97 | 7.734 |

Thus with the conditions assumed, this home would be in a radiation field of approximately 200 r/hr at 1 hour after detonation. Radioactive decay (assuming a $t^{-1.2}$ decay relation) would bring the radiation field down to approximately 13 r/hr at 10 hr after detonation. Removal of a large mass of material during this period would mean a sacrifice of large doses.

MASS REMOVAL FROM CITY STREETS

Visual observation of the reclamation problems in the city of San Jose¹¹ indicated that a critical situation exists for the inhabitants which will compound itself as long as these volcanic eruptions continue. Lack of sufficient mechanized equipment required to remove large volumes of debris imposes a tremendous drainage on manpower availability and is costly. The bulk of the material from the streets is swept by hand and accumulated in several locations for later pickup by trucks. Care has to be taken to keep as much of the debris as possible out of the storm drains in order to keep them open. Considerable redistribution results when accumulated piles of debris are shoveled into dump trucks.

If the debris were radioactive fallout, the slow manual methods employed to remove the volcanic debris could not be used to remove radioactive debris if radiation doses are to be minimized.

CONCLUSIONS

The study with volcanic debris indicated similar conditions would exist in the case of comparable contamination with radioactive fallout.

From the ingress tests it was determined that, an otherwise high protection factor may be reduced to as low as 250, in the vicinity of an open window into which air is moving. Because of the limited area occupied by the major portion of the fallout inside the house, it appears feasible to re-establish high protection factors by such simple countermeasures as rapid sweeping and disposition outside. This would apply only in situations where only a few windows are open and air flow through them is of moderate velocity. Those situations in which a large number of windows are open and large amounts of air flow into shelter spaces would give rise to very different conditions. For example, if Tests Echo and Delta (Patio) are indicative of large areas of open windows, as much as 1/10 of the outside deposit level could be deposited near the windows.

From the exterior tests it was concluded that, in the absence of rain:

1. Particle size distribution is essentially constant for any one day's collection, and varies only slightly from day to day.
2. Mass loading is relatively constant in uncovered areas such as roofs and grounds.
3. Areas, such as the patio, that are covered but exposed to the free movement of outside air, are contaminated by fallout to a lesser degree (about 1/10) than fully exposed surfaces but to a greater degree than ventilated indoor spaces.

On the basis of conclusions 1 and 2, it is further concluded that reclamation tests using uniformly distributed fallout are realistic even when the areas are quite complex.

When rain accompanied a "fallout" event, a different set of conditions existed. Particle size distributions and mass loadings were largely a function of redistribution processes; hence, both varied with

location. Accumulations on sloped roofs and walks were significantly reduced by rain. However, the material from these surfaces was redeposited in gutters and other collection points down slope. Extrapolated to a nuclear fallout situation, this means the creation of concentrated radiation sources. Preparations must be made for the non-manual removal of materials from such places as the gutters to locations remote from the building, if habitation in such a building is required during a fallout event.

REFERENCES

1. W. L. Owen, J. D. Sartor, "Radiological Recovery of Land Target Components, Complex I and Complex II", U. S. Naval Radiological Defense Laboratory, USNRDL-TR-570, 25 May 1962.
2. W. L. Owen, J. D. Sartor, W. H. Van Horn, "Stoneman II Test of Reclamation Performance. Volume II. Performance Characteristics of Wet Decontamination Procedures", U. S. Naval Radiological Defense Laboratory, USNRDL-TR-335, 21 July 1960.
3. H. Lee, J. D. Sartor, W. H. Van Horn, "Stoneman II Test of Reclamation Performance. Volume III. Performance Characteristics of Dry Decontamination Procedures", U. S. Naval Radiological Defense Laboratory, USNRDL-TR-336, 6 June 1959.
4. H. Lee, J. D. Sartor, W. H. Van Horn, "Stoneman II Test of Reclamation Performance. Volume IV. Performance Characteristics of Land Reclamation Procedures", U. S. Naval Radiological Defense Laboratory, USNRDL-TR-337, 12 January 1959.
5. M. M. Bigger, R. J. Crew, R. K. Fuller, "Dose Associated with Particulate Ingress into Prototype Shelter Via the Ventilation System", U. S. Naval Radiological Defense Laboratory, USNRDL-TR-815, 20 January 1965.
6. W. E. Strobe, "Evaluation of Countermeasure System Components and Operational Procedures, Operation PLUMBBOB, Project 32.3", Civil Effects Test Group, AEC, WT-1464, 14 August 1958.
7. C. F. Miller, Fallout and Radiological Countermeasures, Volumes I and II. Stanford Research Institute, January 1963.
8. D. E. Clark Jr., W. C. Cobbin, "Some Relationships Among Particle Size, Mass Level, and Radiation Intensity of Fallout From a Land Surface Nuclear Detonation", U. S. Naval Radiological Defense Laboratory, USNRDL-TR-639, 21 March 1963.
9. C. F. Miller, P. D. LaRiviere, H. Lee, "Operation CFNIZA-ARENA: Summary of Findings About Fallout From Volcano Irazu Obtained During a Trip to Costa Rica", (Preliminary Report), Stanford Research Institute, February 1964.

10. B. H. Evans. Natural Air Flow Around Buildings. Texas Engineering Experiment Station, Research Report No. 59 (March 1957).
11. Ceniza-Arena Cleanup in San Jose, Costa Rica: Operational Aspects as Related to Nuclear Weapon Fallout Decontamination. SRI Project MU-5069.

APPENDIX A

PARTICLE SIZE DISTRIBUTIONS

TABLE A.1

Particle Size Analysis by Sieving - Test Alpha

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | | | | | | |
|----------------------------|------------------------|--------------------------|--------------|---------------|------------------|---------------------|--------|--------|
| | | Exterior Collectors | | | | Interior Collectors | | |
| | | Roof | Side Yard | Front Yard | Intake Window | 1 | 2 | 15 |
| 495 | | - | 0.0227 | - | - | - | - | - |
| 295 | | - | 0.0058 | - | - | 0.0011 | 0.0004 | 0.0013 |
| 246 | | 0.010 | 0.0180 | 0.009 | 0.010 | 0.0013 | 0.0004 | 0.0013 |
| 175 | | 0.022 | 0.0403 | 0.047 | 0.034 | 0.0015 | 0.0014 | 0.0009 |
| 147 | | 0.300 | 0.3915 | 0.495 | 0.403 | 0.0035 | 0.0014 | 0.0038 |
| 104 | | 8.56 | 9.57 | 12.32 | 11.57 | 0.1418 | 0.0100 | 0.0979 |
| 88 | | 7.67 | 6.03 | 8.54 | 9.94 | 0.2023 | 0.0184 | 0.1484 |
| 61 | | 15.25 | 13.15 | 21.27 | 18.74 | 0.5361 | 0.1040 | 0.5072 |
| 43 | | 1.60 | 3.51 | 0.677 | 1.38 | 0.4645 | 0.1399 | 0.3829 |
| On Pan | | 9.52 | 9.40 | 3.80 | 8.03 | 0.5147 | 0.2032 | 0.4717 |
| Total | | 42.9320 | 42.1383 | 47.1580 | 50.107 | 1.8668 | 0.4794 | 1.6144 |

*See Fig. 3.

TABLE A.2

Particle Size Analysis by Sieving - Test Bravo

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | | | | | | Interior Collectors | |
|----------------------------|------------------------|--------------------------|--------------|--------------|---------------|------------------|--------|---------------------|---|
| | | Exterior Collectors | | | | Intake | | 1 | 2 |
| | | Roof | Back Yard | Side Yard | Front Yard | Intake Window | | | |
| 495 | - | - | - | - | - | - | - | - | - |
| 295 | 0.0018 | 0.0017 | 0.0040 | 0.0015 | 0.0012 | | | 0.0036 | |
| 246 | 0.0014 | 0.0019 | 0.0037 | 0.0017 | 0.0021 | | 0.0056 | 0.0007 | |
| 175 | 0.0088 | 0.0116 | 0.0094 | 0.0081 | 0.0132 | | 0.0159 | 0.0010 | |
| 147 | 0.0643 | 0.0795 | 0.0624 | 0.0576 | 0.0840 | | 0.0276 | 0.0017 | |
| 104 | 1.74 | 2.14 | 1.60 | 0.1907 | 1.89 | | 0.3059 | 0.0367 | |
| 88 | 2.14 | 2.74 | 1.90 | 2.27 | 2.40 | | 0.3014 | 0.0727 | |
| 61 | 5.77 | 7.44 | 5.28 | 5.98 | 6.58 | | 0.6300 | 0.2907 | |
| 43 | 3.53 | 3.47 | 3.65 | 4.32 | 3.74 | | 0.4384 | 0.3002 | |
| On Pan | 8.20 | 8.77 | 8.29 | 9.77 | 9.17 | | 0.5317 | 0.3863 | |
| Totals | 21.4563 | 24.6547 | 20.7995 | 22.5996 | 23.8805 | | 2.2565 | 1.0936 | |

*See Fig. 3.

TABLE A.3
Particle Size Analysis by Sieving - Test Charley

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | | | | | | |
|----------------------------|------------------------|--------------------------|--------------|--------------|---------------------|------------------|--------|--------|
| | | Exterior Collectors | | | Interior Collectors | | | |
| | | Roof | Back Yard | Side Yard | Front Yard | Intake Window | 1 | 2 |
| | | | | | | | | 15 |
| 295 | | 0.0139 | 0.0292 | 0.0368 | 0.0355 | 0.0186 | 0.0014 | 0.0005 |
| 246 | | 0.0413 | 0.0780 | 0.0750 | 0.0458 | 0.0578 | 0.0012 | 0.0005 |
| 175 | | 0.7353 | 1.02 | 0.9079 | 0.8807 | 0.81 | 0.0236 | 0.0036 |
| 147 | | 2.31 | 3.13 | 2.81 | 2.75 | 2.47 | 0.1574 | 0.0080 |
| 104 | | 1.31 | 15.74 | 14.39 | 13.86 | 12.01 | 1.56 | 0.0836 |
| 88 | | 4.09 | 5.41 | 5.14 | 5.14 | 4.35 | 1.04 | 0.1335 |
| 61 | | 3.32 | 5.69 | 4.84 | 4.34 | 3.33 | 1.11 | 0.3372 |
| 43 | | 1.27 | 1.89 | 1.84 | 1.46 | 1.15 | 0.5371 | 0.2463 |
| On Pan | | 1.77 | 3.21 | 2.49 | 2.08 | 1.63 | 0.7809 | 0.2449 |
| Total | | 14.8605 | 36.1972 | 32.5297 | 30.5920 | 25.8264 | 5.2616 | 1.0581 |
| | | | | | | | | 1.1743 |

*See Fig. 3.

TABLE A.4

Particle Size Analysis by Sieving - Test Foxtrot

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | | | | | Front | | Chimney |
|----------------------------|------------------------|--------------------------|---------|---------|--------------|--------------|---------|---------|---------|
| | | P-2 | P-3 | P-6 | Back Yard | Side Yard | Yard | Yard | |
| 295 | | 0.0252 | 0.0146 | 0.0177 | 0.0023 | 0.0099 | 0.0047 | 0.0065 | |
| 246 | | 0.0148 | 0.0046 | 0.0059 | 0.0009 | 0.0025 | 0.0007 | 0.0067 | |
| 175 | | 0.0417 | 0.0146 | 0.0091 | 0.0046 | 0.0044 | 0.0033 | 0.0142 | |
| 147 | | 0.0433 | 0.0175 | 0.0193 | 0.0228 | 0.0160 | 0.0129 | 0.0274 | |
| 104 | | 0.1743 | 0.2181 | 0.4082 | 0.4492 | 0.4048 | 0.4763 | 0.4792 | |
| 88 | | 0.2141 | 0.3822 | 0.6170 | 0.6517 | 0.6340 | 0.8067 | 0.6732 | |
| 61 | | 0.5288 | 0.8353 | 1.2150 | 1.5714 | 1.4418 | 1.7583 | 1.2645 | |
| 43 | | 0.3911 | 0.5034 | 0.7450 | 1.0895 | 0.9635 | 1.2145 | 0.7926 | |
| < 43 | | 0.4509 | 0.7659 | 1.0102 | 1.5464 | 1.4243 | 1.7199 | 1.0275 | |
| Loss (+) or gain (-)** | | -0.0325 | -0.0037 | +0.0438 | +0.0153 | +0.0457 | +0.0191 | -0.0148 | |
| Total | | 1.8517 | 2.7525 | 4.0912 | 5.3541 | 4.9012 | 6.0165 | 4.2770 | |

* See Fig. 4.

** Uncontrollable losses or gains due to sieving operations.

TABLE A.5
Particle Size Analysis by Sieving - Test
Golf

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | | |
|----------------------------|------------------------|--------------------------|--------|--------|
| | | AOC-3 | AOC-5 | AOC-8 |
| 295 | | 0.0079 | 0.0140 | 0.0086 |
| 246 | | 0.0057 | 0.0052 | 0.0065 |
| 175 | | 0.0126 | 0.0128 | 0.0155 |
| 147 | | 0.0337 | 0.0407 | 0.0429 |
| 104 | | 0.5651 | 0.5794 | 0.5282 |
| 88 | | 0.8072 | 0.7732 | 0.6991 |
| 61 | | 1.7241 | 1.7527 | 1.6209 |
| 43 | | 1.1325 | 1.0201 | 0.9933 |
| < 43 | | 1.4561 | 1.3281 | 1.2997 |
| Loss** | | 0.0291 | 0.0495 | 0.0736 |
| Total | | 5.7740 | 5.5757 | 5.2883 |

* See Fig. 4.

**Uncontrollable losses due to sieving operations.

TABLE A.6

Particle Size Analysis by Sieving - Test Hotel

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | |
|----------------------------|------------------------|--------------------------|---------|
| | | P-1 | Chimney |
| 295 | | 0.1045 | 0.0084 |
| 246 | | 0.0805 | 0.0043 |
| 175 | | 0.2765 | 0.0220 |
| 147 | | 0.3050 | 0.0344 |
| 104 | | 0.7173 | 0.1317 |
| 88 | | 0.4111 | 0.0999 |
| 61 | | 0.5831 | 0.1922 |
| 43 | | 0.3453 | 0.1085 |
| < 43 | | 0.5095 | 0.1568 |
| Loss** | | 0.0270 | 0.0009 |
| Total | | 3.3598 | 0.7591 |

* See Fig. 4.

**Uncontrollable losses due to sieving operations.

TABLE A.7

Particle Size Analysis by Sieving - Test India

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | | | |
|----------------------------|------------------------|--------------------------|--------|---------|---------|
| | | AOC-5 | AOC-6 | AOC-8 | AOC-9 |
| 295 | | 0.1018 | 0.0848 | 0.2035 | 0.3641 |
| 247 | | 0.0104 | 0.0373 | 0.2948 | 0.5326 |
| 175 | | 0.0335 | 0.1459 | 1.5047 | 2.8355 |
| 147 | | 0.0527 | 0.2120 | 2.7420 | 5.4074 |
| 104 | | 0.3147 | 0.7026 | 7.9056 | 17.0675 |
| 88 | | 0.3603 | 0.5955 | 3.8255 | 7.7098 |
| 61 | | 0.3632 | 0.9564 | 4.9649 | 10.5651 |
| 43 | | 0.4689 | 0.5782 | 2.4097 | 4.0964 |
| < 43 | | 0.8600 | 0.9143 | 3.4883 | 7.0116 |
| Loss** | | 0.3294 | 0.0313 | 0.0700 | 0.1686 |
| Total | | 2.8949 | 4.2583 | 27.4090 | 55.7581 |

* See Fig. 4.

**Uncontrollable losses due to sieving operations.

TABLE A.8

Particle Size Analysis by Sieving - Test Juliet

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | | | |
|----------------------------|------------------------|--------------------------|--------|---------------|---------|
| | | P-2 | P-5 | Front Yard | Chimney |
| 295 | | 0.0316 | 0.0031 | 0.0014 | 0.0010 |
| 246 | | 0.0052 | 0.0040 | 0.0001 | 0.0013 |
| 175 | | 0.0143 | 0.0110 | 0.0060 | 0.0064 |
| 147 | | 0.0278 | 0.0726 | 0.0807 | 0.0701 |
| 104 | | 0.4079 | 2.0337 | 2.4088 | 1.9975 |
| 88 | | 0.2687 | 1.2321 | 1.4263 | 1.1363 |
| 61 | | 0.4022 | 1.3989 | 1.7269 | 1.4290 |
| 43 | | 0.2518 | 0.9398 | 1.0761 | 0.9010 |
| < 43 | | 0.4659 | 2.2160 | 2.5787 | 1.9974 |
| Loss** | | 0.0204 | 0.0235 | 0.0362 | 0.0114 |
| Total | | 1.8958 | 7.9347 | 9.3412 | 7.5514 |

* See Fig. 4

**Uncontrollable losses due to sieving operations.

TABLE A.9

Particle Size Analysis by Sieving - Test Kilo

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | | | |
|----------------------------|------------------------|--------------------------|--------|--------|--------|
| | | AOC-2 | AOC-5 | AOC-6 | AOC-8 |
| 295 | | 0.0049 | 0.0081 | 0.0050 | 0.0032 |
| 246 | | 0.0028 | 0.0060 | 0.0010 | 0.0015 |
| 175 | | 0.0165 | 0.0104 | 0.0087 | 0.0120 |
| 147 | | 0.0910 | 0.1185 | 0.0682 | 0.1039 |
| 104 | | 2.3982 | 2.4884 | 1.7263 | 2.3932 |
| 88 | | 1.4398 | 1.4412 | 1.0302 | 1.3323 |
| 61 | | 1.8763 | 1.5580 | 1.2518 | 1.7126 |
| 43 | | 0.9294 | 1.0039 | 0.7527 | 1.0065 |
| < 43 | | 2.5104 | 2.2117 | 1.7842 | 2.4880 |
| Loss** | | 0.0305 | 0.0309 | 0.0118 | 0.0278 |
| Total | | 9.2998 | 8.8771 | 6.6405 | 9.0810 |

* See Fig. 4

**Uncontrollable losses due to sieving operations.

TABLE A.10

Particle Size Analysis by Sieving - Test Lima

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve | | | |
|----------------------------|------------------------|--------------------------|--------------|---------------|--------------|
| | | AOC- North | AOC- East | AOC- South | AOC- West |
| 295 | | 0.0020 | 0.0074 | 0.0122 | 0.0009 |
| 246 | | 0.0048 | 0.0046 | 0.0011 | 0.0010 |
| 175 | | 0.0102 | 0.0075 | 0.0077 | 0.0062 |
| 147 | | 0.0870 | 0.0873 | 0.0866 | 0.0823 |
| 104 | | 2.1945 | 2.1398 | 2.3786 | 2.3497 |
| 88 | | 1.3673 | 1.3135 | 1.4207 | 1.3434 |
| 61 | | 1.5896 | 1.5431 | 1.7674 | 1.7828 |
| 43 | | 1.0685 | 0.9818 | 0.9372 | 0.9447 |
| < 43 | | 2.0851 | 2.3299 | 2.4781 | 2.4137 |
| Loss** | | 0.0363 | 0.0188 | 0.0285 | 0.0180 |
| Total | | 8.4453 | 8.4337 | 9.1181 | 8.9427 |

* See Fig. 4

**Uncontrollable losses due to sieving operations.

TABLE A.11

Particle Size Analysis by Sieving - Test Mike

| Sieve Size (μ) | Collector Location* | Grams Remaining on Sieve |
|----------------------------|------------------------|--------------------------|
| | | F-1 |
| 295 | | 0.1110 |
| 246 | | 0.1198 |
| 175 | | 0.3801 |
| 147 | | 0.4900 |
| 104 | | 3.1577 |
| 88 | | 3.7056 |
| 61 | | 15.8761 |
| 43 | | 6.2842 |
| < 43 | | 11.5671 |
| Loss** | | 0.0667 |
| Total | | 41.7583 |

* See Fig. 1.

**Uncontrollable losses due to sieving operations.

TABLE A.12

Particle Size Analysis by Sieving - Test November

| Sieve Size (μ) | Collector Location*: | Grams Remaining on Sieve | | | | |
|----------------------|-------------------------|--------------------------|---------------|--------------|---------------|--------------|
| | | Chimney | AOC- North | AOC- East | AOC- South | AOC- West |
| 295 | | 0.0023 | 0.0045 | 0.0041 | 0.0017 | 0.0039 |
| 247 | | 0.0120 | 0.0023 | 0.0015 | 0.0011 | 0.0032 |
| 175 | | 0.0116 | 0.0104 | 0.0102 | 0.0042 | 0.0133 |
| 147 | | 0.0730 | 0.0562 | 0.0662 | 0.0196 | 0.0663 |
| 104 | | 1.5846 | 1.3106 | 1.6503 | 0.6766 | 1.4124 |
| 88 | | 2.1977 | 1.9292 | 2.3365 | 0.9596 | 1.7960 |
| 61 | | 8.7030 | 7.0282 | 9.6215 | 3.6765 | 7.8197 |
| 43 | | 7.8810 | 7.1045 | 6.7644 | 4.3278 | 5.7160 |
| < 13 | | 9.8653 | 7.2709 | 9.1794 | 4.6528 | 6.9190 |
| Loss** | | 0.0660 | 0.0445 | 0.0534 | 0.0473 | 0.0350 |
| Total | | 30.3305 | 24.7613 | 29.6875 | 14.3672 | 23.7848 |

* See Fig. 4.

**Uncontrollable losses due to sieving operations.

TABLE A.13

Particle Size Analysis by Sieving - Test Papa

| Sieve Size (μ) | Collector Location*: | Grams Remaining on Sieve | |
|----------------------------|-------------------------|--------------------------|--------|
| | | Chimney | F-1 |
| 295 | | 0.0026 | 0.0044 |
| 246 | | 0.0017 | 0.0025 |
| 175 | | 0.0133 | 0.0188 |
| 147 | | 0.0650 | 0.0827 |
| 104 | | 0.2570 | 0.4297 |
| 88 | | 0.3426 | 0.6352 |
| 61 | | 1.1720 | 2.4216 |
| 43 | | 0.9797 | 2.1774 |
| < 43 | | 1.3111 | 2.8010 |
| Loss** | | 0.0120 | 0.0480 |
| Total | | 4.1570 | 8.6213 |

* See Fig. 4

**Uncontrollable losses due to sieving operations.

APPENDIX B

MASS DEPOSITED

TABLE B.1

Summary of Mass Deposited

| Station* | Mass (g/ft ²) | | |
|---------------|---------------------------|------------|--------------|
| | Test Alpha | Test Bravo | Test Charley |
| Roof | 10.74 | 5.36 | 3.72 |
| Back Yard | lost | 6.17 | 9.05 |
| Side Yard | 10.53 | 5.20 | 8.13 |
| Front Yard | 11.79 | 5.65 | 7.65 |
| Intake Window | 12.53 | 5.97 | 6.46 |
| 1 | 0.468 | 0.5650 | 1.32 |
| 2 | 0.1199 | 0.2725 | 0.265 |
| 3 | 0.0047 | 0.0094 | 0.0009 |
| 4 | lost | 0.0046 | 0.0030 |
| 5 | 0.0036 | 0.0051 | 0.0025 |
| 6 | 0.0064 | 0.1044 | 0.1235 |
| 7 | 0.0035 | 0.0086 | 0.0143 |
| 8 | 0.0241 | 0.0074 | 0.0107 |
| 9 | 0.0055 | 0.0160 | 0.0393 |
| 10 | 0.0065 | 0.0244 | 0.0081 |
| 11 | 0.0065** | 0.0120** | 0.0227 |
| 12 | 0.0207 | 0.0038 | 0.0128 |
| 13 | 0.0085 | 0.0073 | 0.0057 |
| 14 | 0.0039** | 0.0077 | 0.0494 |
| 15 | 0.4025 | 0.0044 | 0.2925*** |

* See Fig. 3.

**Contained paint chips.

***Leak in sealing tape near fan.

TABLE B.2

Summary of Mass Deposited

| Location* | Mass (g/ft ²) | | | | | |
|-----------------|---------------------------|-------|--------|--------|--------|-------|
| | Foxtrot | Golf | Hotel | India | Juliet | Kilo |
| Patio P-1 | 0.986 | | 0.833 | | 1.722 | |
| P-2 | 0.464 | | 10.605 | | 0.474 | |
| P-3 | 0.690 | | 7.711 | | 0.904 | |
| P-4 | 0.732 | | 7.506 | | 1.211 | |
| P-5 | 1.175 | | 1.622 | | 1.983 | |
| P-6 | 1.041 | | 1.661 | | 1.770 | |
| Back Walk AOC-1 | | 1.409 | | 2.883 | | 2.355 |
| AOC-2 | | 1.420 | | 6.843 | | 2.317 |
| AOC-3 | | 1.445 | | 15.285 | | 2.296 |
| AOC-4 | | 1.378 | | 0.832 | | 2.319 |
| AOC-5 | | 1.396 | | 0.641 | | 2.212 |
| AOC-6 | | 1.309 | | 1.057 | | 1.657 |
| AOC-7 | | 1.338 | | 0.609 | | 2.290 |
| AOC-8 | | 1.324 | | 6.835 | | 2.263 |
| AOC-9 | | 1.413 | | 13.898 | | 2.146 |
| Back Yard | 1.340 | | 0.786 | | 2.342 | |
| Side Yard | 1.287 | | 0.617 | | 1.844 | |
| Front Yard | 1.506 | | 0.209 | | 2.335 | |
| Chimney | 1.070 | | 0.190 | | 1.888 | |

*See Fig. 4 for sample locations.

TABLE B.3

Summary of Deposit Collected

| Location* | Mass (g/ft ²) | | | | |
|-----------------|---------------------------|--------|----------|-------|-------|
| | Lima | Mike | November | Papa | Romeo |
| Front Walk F-1 | | 9.839 | | 1.985 | |
| F-2 | | 10.432 | | 2.143 | |
| Back Walk R-1** | | | | | 0.586 |
| R-2** | | | | | 0.509 |
| R-3** | | | | | 0.528 |
| R-4** | | | | | 0.506 |
| R-5** | | | | | 0.476 |
| Roof Chimney | | | 7.583 | 1.036 | |
| AOC North | 2.102 | | 6.179 | | |
| AOC East | 2.104 | | 7.409 | | |
| AOC South | 2.272 | | 3.580 | | |
| AOC West | 2.231 | | 5.938 | | |

* See Figure 4 for sample locations.

**See Figure B.1 for Romeo sample locations.

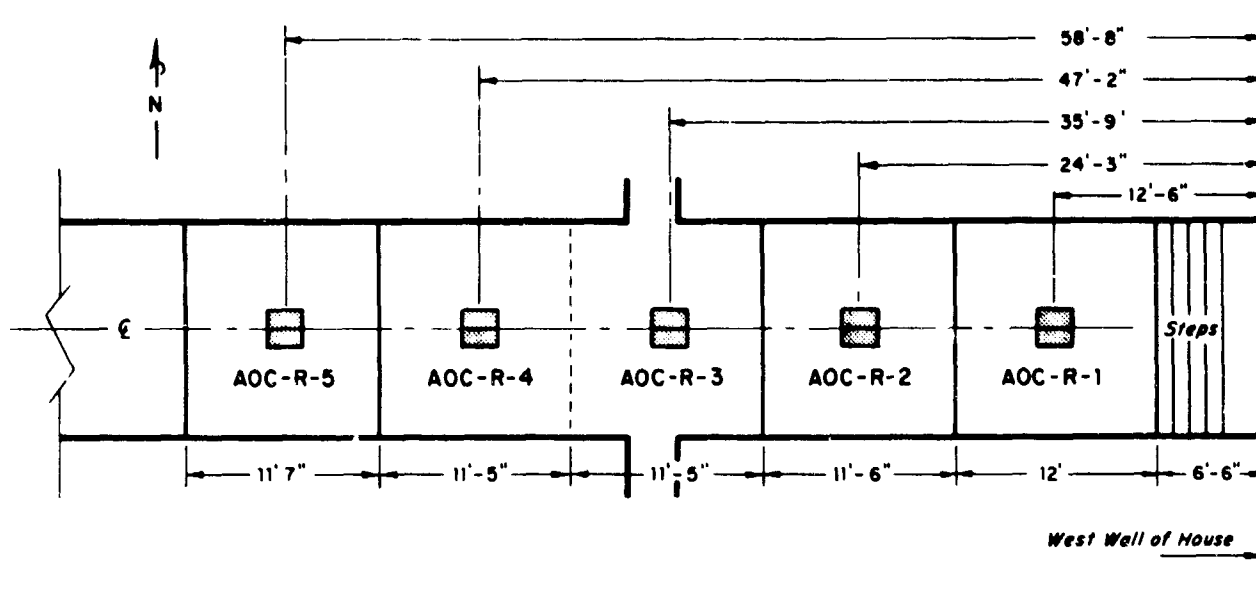


Fig. B.1 Test Romeo Station Locations Back Walkway - Concrete Surface

APPENDIX C

WEATHER DATA

TABLE C.1
Relative Humidity and Temperature

| Time | April 24 | | April 25 | | April 26 | | April 27 | |
|------|---------------|------------|---------------|------------|---------------|------------|---------------|------------|
| | Rel. Hum. (%) | Temp. (°F) | Rel. Hum. (%) | Temp. (°F) | Rel. Hum. (%) | Temp. (°F) | Rel. Hum. (%) | Temp. (°F) |
| 0800 | | | 80 | 68 | 76 | 69 | 78 | 69 |
| 0900 | | | 81 | 69 | 77 | 69 | 81 | 70 |
| 1000 | 76 | 71 | 80 | 69 | 78 | 70 | 80 | 70 |
| 1100 | 78 | 72 | 77 | 70 | 76 | 70 | 77 | 72 |
| 1200 | 79 | 72 | 77 | 71 | 76 | 70 | 76 | 72 |
| 1300 | 77 | 72 | 76 | 71 | 76 | 71 | 75 | 75 |
| 1400 | 77 | 72 | 77 | 71 | 77 | 71 | 76 | 71 |
| 1500 | 78 | 71 | 76 | 71 | 77 | 71 | 86 | 67 |
| 1600 | 79 | 70 | 77 | 72 | 77 | 71 | 90 | 67 |
| 1700 | 80 | 70 | 77 | 71 | 77 | 71 | 90 | 67 |
| 1800 | 80 | 70 | 77 | 71 | 78 | 71 | 90 | 67 |
| 1900 | 80 | 70 | 77 | 71 | 78 | 71 | 90 | 67 |
| 2000 | 80 | 69 | 77 | 70 | 79 | 71 | 90 | 67 |
| 2100 | 80 | 69 | 76 | 70 | 79 | 71 | 90 | 66 |
| 2200 | 80 | 69 | 77 | 70 | 79 | 70 | 90 | 66 |
| 2300 | 80 | 69 | 77 | 69 | 79 | 70 | 90 | 66 |
| 2400 | 80 | 69 | 77 | 69 | 79 | 70 | 90 | 65 |
| 0100 | 80 | 68 | 76 | 69 | 79 | 70 | 90 | 65 |
| 0200 | 80 | 68 | 76 | 69 | 79 | 70 | 88 | 65 |
| 0300 | 80 | 69 | 76 | 69 | 79 | 70 | 88 | 64 |
| 0400 | 80 | 68 | 76 | 69 | 79 | 69 | 88 | 63 |
| 0500 | 80 | 68 | 76 | 69 | 79 | 70 | 87 | 63 |
| 0600 | 80 | 68 | 76 | 69 | 78 | 69 | 86 | 63 |
| 0700 | 80 | 68 | 76 | 69 | 78 | 69 | 87 | 64 |
| | | | | | | | | |
| | 28 April | | 29 April | | 2 May | | 4 May | |
| 0800 | 80 | 70 | 90 | 66 | 85 | 65 | 81 | 68 |
| 0900 | 72 | 68 | 86 | 69 | 83 | 70 | 78 | 72 |
| 1000 | 74 | 72 | 81 | 70 | - | - | 72 | 74 |
| 1100 | 74 | 72 | 77 | 72 | 72 | 75 | 70 | 74 |
| 1200 | 76 | 72 | 73 | 74 | 72 | 75 | 70 | 75 |
| 1300 | 77 | 72 | 72 | 74 | 73 | 73 | 70 | 75 |
| 1400 | 77 | 73 | 69 | 76 | 77 | 71 | 73 | 77 |
| 1500 | 83 | 71 | 69 | 75 | 81 | 70 | 75 | 75 |
| 1600 | 82 | 70 | 73 | 72 | 90 | 70 | 85 | 73 |
| 1700 | 85 | 68 | 81 | 71 | 87 | 68 | 84 | 70 |
| 1800 | 87 | 67 | 85 | 69 | 87 | 67 | 87 | 68 |
| 1900 | 88 | 66 | 86 | 68 | 88 | 67 | 88 | 68 |
| 2000 | 89 | 66 | 87 | 66 | 88 | 66 | 91 | 67 |
| 2100 | 88 | 66 | 87 | 67 | 88 | 65 | 90 | 67 |
| 2200 | 88 | 66 | 88 | 67 | 88 | 64 | 91 | 67 |
| 2300 | 88 | 66 | 88 | 66 | 87 | 63 | 90 | 66 |
| | | | | | | | | |
| | April 29 | | May 1 | | May 3 | | May 5 | |
| 0000 | 88 | 65 | 88 | 66 | 87 | 62 | 89 | 64 |
| 0100 | 88 | 65 | 88 | 65 | 88 | 62 | 86 | 61 |
| 0200 | 88 | 65 | 86 | 64 | 89 | 63 | 85 | 59 |
| 0300 | 88 | 65 | 86 | 64 | 89 | 63 | 85 | 62 |
| 0400 | 89 | 65 | 85 | 63 | 88 | 62 | 85 | 59 |
| 0500 | 89 | 66 | 84 | 63 | 88 | 61 | 85 | 59 |

Continued

TABLE C.1 (Cont'd)

Relative Humidity and Temperature

| Time | April 29 | | May 1 | | May 3 | | May 5 | |
|------|------------------|---------------|------------------|---------------|------------------|---------------|------------------|---------------|
| | Rel. Hum. (%) | Temp. (°F) | Rel. Hum. (%) | Temp. (°F) | Rel. Hum. (%) | Temp. (°F) | Rel. Hum. (%) | Temp. (°F) |
| 0600 | 89 | 67 | 83 | 63 | 88 | 62 | 85 | 61 |
| 0700 | 89 | 66 | 83 | 65 | 87 | 65 | 84 | 64 |
| 0800 | 88 | 67 | 83 | 67 | 84 | 70 | 80 | 68 |
| 0900 | 87 | 69 | 79 | 72 | 78 | 70 | 74 | 71 |
| 1000 | 82 | 69 | 70 | 76 | 74 | 72 | 74 | 73 |
| 1100 | 82 | 68 | 67 | 77 | 71 | 74 | 74 | 74 |
| 1200 | 84 | 70 | 67 | 76 | 73 | 72 | 71 | 75 |
| 1300 | 81 | 73 | 69 | 75 | 77 | 72 | 71 | 75 |
| 1400 | 80 | 73 | 70 | 77 | 77 | 73 | 68 | 77 |
| 1500 | 77 | 73 | 70 | 76 | 74 | 71 | 74 | 73 |
| 1600 | 78 | 73 | 70 | 73 | 81 | 70 | 80 | 72 |
| 1700 | 81 | 70 | 75 | 71 | 83 | 68 | 81 | 70 |
| 1800 | 84 | 63 | 70 | 69 | 86 | 67 | 83 | 69 |
| 1900 | 87 | 67 | 80 | 68 | 87 | 66 | * | * |
| 2000 | 88 | 67 | 84 | 67 | 88 | 65 | | |
| 2100 | 88 | 67 | 84 | 67 | 87 | 67 | | |
| 2200 | 89 | 66 | 85 | 66 | 87 | 63 | | |
| 2300 | 89 | 66 | 85 | 65 | 86 | 63 | | |
| | | | | | | | | |
| | <u>May 2</u> | | <u>May 4</u> | | | | | |
| 0000 | 89 | 65 | 85 | 64 | 87 | 62 | | |
| 0100 | 89 | 65 | 85 | 63 | 87 | 61 | | |
| 0200 | 95 | 65 | 86 | 63 | 86 | 60 | | |
| 0300 | 89 | 64 | 87 | 62 | 87 | 61 | | |
| 0400 | 89 | 63 | 87 | 61 | 83 | 60 | | |
| 0500 | 89 | 62 | 87 | 61 | 83 | 60 | | |
| 0600 | 88 | 62 | 87 | 61 | 84 | 61 | | |
| 0700 | 88 | 64 | 87 | 63 | 82 | 63 | | |
| | | | | | | | | |
| | <u>May 6</u> | | <u>May 7</u> | | <u>May 8</u> | | | |
| 0800 | | | | | 85 | 67 | | |
| 0900 | 73 | 73 | 76 | 71 | 80 | 69 | | |
| 1000 | 71 | 75 | 72 | 71 | 73 | 73 | | |
| 1100 | 71 | 76 | 71 | 74 | 73 | 71 | | |
| 1200 | 70 | 78 | 72 | 72 | 73 | 73 | | |
| 1300 | 69 | 78 | 72 | 72 | 75 | 72 | | |
| 1400 | 69 | 78 | 71 | 73 | 75 | 71 | | |
| 1500 | 76 | 74 | 76 | 69 | 73 | 71 | | |
| 1600 | 75 | 73 | 78 | 67 | 78 | 67 | | |
| 1700 | 77 | 70 | 81 | 66 | 78 | 68 | | |
| 1800 | 80 | 68 | 82 | 65 | 79 | 67 | | |
| 1900 | 85 | 67 | 83 | 64 | 81 | 66 | | |
| 2000 | 84 | 66 | 86 | 64 | 83 | 66 | | |
| 2100 | 83 | 66 | 86 | 63 | 84 | 65 | | |
| 2200 | 85 | 64 | 87 | 63 | 85 | 64 | | |
| 2300 | 86 | 65 | 89 | 62 | 86 | 64 | | |
| 0000 | 86 | 64 | 89 | 61 | 85 | 63 | | |
| 0100 | 86 | 63 | 89 | 62 | 86 | 63 | | |
| 0200 | 86 | 63 | 87 | 62 | 86 | 63 | | |
| 0300 | 86 | 63 | 88 | 62 | 87 | 62 | | |
| 0400 | 86 | 63 | 90 | 61 | 87 | 61 | | |
| 0500 | 87 | 63 | 89 | 61 | 87 | 61 | | |
| 0600 | 84 | 63 | 89 | 61 | 87 | 61 | | |
| 0700 | 83 | 65 | 89 | 63 | 88 | 62 | | |
| | | | | | | | | |
| | | | <u>May 9</u> | | | | | |
| | | | 86 | 66 | | | | |

TABLE C.2

Rain Data

| Date and Time | Amount of Rain (in.) | | | | | Remarks |
|---------------|----------------------|-----------|-----------|-------|---------|--|
| | Front Yard | Side Yard | Back Yard | Roof | Average | |
| Apr 23 | | | | | | |
| 0900 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | No rain during night. |
| 1145 | | | | | | Rain starts. |
| 1245 | 0.14 | 0.12 | 0.125 | 0.135 | 0.13 | Rain stops. (15 min. heavy rain) |
| Apr 24 | | | | | | |
| 0930 | 0.14 | 0.12 | 0.13 | 0.14 | 0.13 | Rainfall during night. |
| 1400 | | | | | | Rain started. |
| 1415 | 0.04 | | | | | |
| 1440 | 0.08 | | | | | |
| 1500 | 0.14 | | | | | |
| 1530 | 0.24 | | | | | |
| 1605 | 0.39 | | | | | |
| 1620 | 0.43 | | | | | |
| 1830 | | | | | | Approximate time rain stops. |
| Apr 25 | | | | | | |
| 0930 | 0.02 | 0.61 | 0.61 | 0.61 | 0.61 | Rain since 0930 Apr 24 = 0.18-0.19 in. rain since 1830 Apr 24 |
| 1232 | | | | | | Light drizzle, stopped after few minutes. |
| Apr 26 | | | | | | |
| 0730 | 0.84 | 0.83 | 0.81 | 0.82 | 0.82 | Rain at night, duration unknown. |
| Apr 27 | | | | | | |
| 0900 | 0.01 | trace | trace | trace | trace | Rainfall during night. |
| 1052 | | | | | | Light sprinkle starts. |
| 1400 | | | | | | Heavy rain starts. |
| 1405 | 0.09 | | | | | Medium rain. |
| 1410 | 0.12 | | | | | |
| 1415 | 0.155 | | | | | |
| 1430 | 0.29 | | | | | |
| 1436 | 0.66 | | | | | |
| 1445 | 0.81 | | | | | |
| 1450 | 0.82 | | | | | |
| 1455 | 0.83 | | | | | |
| 1500 | 0.84 | | | | | |
| 1525 | 0.85 | | | | | |
| 1500 | 0.87 | | | | | |
| Apr 28 | | | | | | |
| 0615 | 0.87 | 0.85 | 0.87 | 0.84 | 0.85 | Rain since 0900 Apr 27. |
| 1240 | | | | | | Light rain starts. |
| 1345 | trace | | | | | Light rain stops. |
| 1410 | | | | | | Rain starts. |
| 1415 | 0.04 | | | | | |
| 1430 | 0.05 | | | | | |
| 1435 | 0.06 | | | | | |
| 1430 | 0.09 | | | | | |
| 1445 | 0.09 | | | | | Rain stops. |
| Apr 29 | | | | | | |
| 0645 | 0.10 | 0.07 | 0.10 | 0.095 | 0.10 | Rain since 0615 Apr 28. |
| 0740 | | | | | | Light rain starts. Approx. 0.1 in. of rain since 1445 Apr. 28. |
| 1000 | 0.01 | | | | | |
| 1005 | 0.06 | | | | | |
| 1010 | 0.09 | | | | | |
| 1030 | 0.075 | | | | | |
| Continued | | | | | | |

TABLE C.2 (Cont'd)

Rain Data

| Date and Time | Amount of Rain (in.) | | | | | Remarks |
|---------------|----------------------|-----------|-----------|-------|---------|--|
| | Front Yard | Side Yard | Back Yard | Roof | Average | |
| 1055 | 0.105 | | | | | |
| 1100 | 0.11 | | | | | |
| 1105 | 0.12 | | | | | |
| 1115 | 0.17 | | | | | |
| 1130 | 0.19 | | | | | |
| 1135 | 0.215 | | | | | |
| 1145 | 0.225 | | | | | Rain stops. |
| Apr 30 | | | | | | |
| 0945 | 0.225 | 0.19 | 0.225 | 0.22 | 0.22 | No measureable rain since 1145 Apr 29. |
| 1452 | | | | | | Light drizzle starts. |
| 1600 | Trace | | | | | Light drizzle stops. |
| May 1 | | | | | | |
| 0915 | 0.01 | 0.005 | 0.01 | 0.005 | 0.005 | Rain during night. |
| May 2 | | | | | | |
| 0845 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | No rain since 0915 May 1. |
| 1300 | | | | | | Light drizzle starts. |
| 1310 | | | | | | Light drizzle stops. |
| 1400 | | | | | | Light drizzle starts. |
| 1405 | trace | | | | | Ceniza noted in rain drops. |
| May 2 | | | | | | |
| 1410 | 0.005 | | | | | |
| 1420 | 0.01 | | | | | |
| 1425 | 0.015 | | | | | |
| 1430 | 0.025 | | | | | |
| 1435 | 0.04 | | | | | |
| 1440 | 0.05 | | | | | |
| 1450 | 0.05 | | | | | Rain stops. |
| May 3 | | | | | | |
| 0800 | 0.05 | 0.04 | 0.05 | 0.05 | 0.05 | Rain since 1300 May 2. No measureable rain since 1450 May 2. |
| May 4 | | | | | | |
| 0900 | 0.05 | 0.055 | 0.05 | 0.05 | 0.05 | Rain during night. |
| 1550 | | | | | | Rain starts. |
| 1555 | 0.025 | | | | | |
| 1600 | 0.055 | | | | | |
| 1605 | 0.07 | | | | | |
| 1615 | 0.07 | | | | | |
| 1620 | 0.09 | | | | | |
| 1640 | 0.10 | | | | | |
| 1645 | 0.125 | | | | | |
| 1650 | 0.135 | | | | | |
| 1705 | 0.135 | | | | | |
| 1710 | 0.15 | | | | | |
| 1725 | 0.15 | | | | | Rain stops. |
| May 5 | | | | | | |
| 0900 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | Rain since 0900 May 4. No measureable rain since 1725 May 4. |
| 1425 | | | | | | Hard rain starts. |
| 1430 | 0.05 | | | | | |
| 1435 | 0.16 | | | | | |
| 1440 | 0.20 | | | | | |
| 1455 | 0.20 | | | | | Rain stops. |

Continued

TABLE C.2 (Cont'd)

Rain Data

| Date and Time | Amount of Rain (in.) | | | | | Remarks |
|----------------|----------------------|-----------|-----------|------|---------|---|
| | Front Yard | Side Yard | Back Yard | Roof | Average | |
| May 6 0900 | 0.20 | 0.08 | 0.20 | 0.19 | 0.19 | Rain since 0900 May 5. No rain since 1455 May 5. |
| May 7 | | | | | | No precipitation. |
| May 8 1545 | | | | | | First precipitation since rain gage was cleaned at 0900 May 6. |
| May 9 0900 | Trace | | | | | Rain at 1545 8 May was very slight. |
| May 10 0900 | 0.00 | | | | | No rain since 1545 8 May. |
| 1600 | | | | | | Rain starts. |
| 1605 | 0.005 | | | | | |
| 1610 | 0.035 | | | | | Light sprinkle starts. |
| 1615 | 0.05 | | | | | |
| May 11 1100 | 0.15 | | | | | Total precipitation since 0900 10 May. |

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| 4. DESCRIPTIVE NOTES (Type of report and inclusive dates) | | |
| 5. AUTHOR(S) (Last name, first name, initial) Kawahara, F. K. Crew, Robert J. | | |
| 6. REPORT DATE 28 February 1966 | 7a. TOTAL NO. OF PAGES 64 | 7b. NO. OF REFS 11 |
| 8a. CONTRACT OR GRANT NO. | 9a. ORIGINATOR'S REPORT NUMBER(S) USNRDL-AR-953 | |
| b. PROJECT NO. OCD Subtask 3118A | 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) OCD 3118A | |
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| 13. ABSTRACT The sand-like debris from Volcano Irazu in Costa Rica closely resembles the type of fallout produced by a near-surface or underground nuclear detonation. The activity of the volcano during April and May 1964 presented an opportunity to use this phenomenon in a field-scale study of some relationships between urban reclamation and nuclear fallout contamination. The eruptions of the volcano were frequent and the rates of arrival at the test site were dependent on wind direction and the severity of the eruptions. The investigation was divided into two phases: (I) distribution of debris inside a one-story residence; and (II) distribution outside the residence. Phase I was concerned with the ingress of particles through open windows under conditions of: (a) natural ventilation, (b) forced ventilation, and (c) forced ventilation with minimal filtering. Phase II was concerned with the deposition and redistribution by wind, of particles on concrete walks, corrugated metal roofs, and partially exposed tile floors - each with and without rain. In Phase I, it was observed that particle size distributions inside the house did not differ greatly from those deposited outside. Mass loadings inside were a factor of 50 less than those outside. It was concluded that, if this were a case of radioactive fallout, the ratio of outside dose to inside dose would be reduced significantly in the vicinity of the window through which air is moving. In Phase II, was observed that in the absence of rain, the particle size distribution and mass deposited was uniform from one sample location to another, only minor variations having been observed from day to day. On this (Abstract continued on last page) | | |

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| b. PROJECT NO. | 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) OCD-3118A | |
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| 13. ABSTRACT (Abstract continued from another page) basis, it was concluded that reclamation tests using uniformly distributed synthetic fallout are realistic even when the surface configurations are quite complex. When rain accompanied the debris deposition, however, different results were observed. Particle size distributions and mass loadings were a function of redistribution and varied with sample location. Deposits on roof surfaces will be significantly reduced but will accumulate in the gutters. In the case of radioactive fallout, a concentrated radiation source would result. | | |

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